MB
4-6-86

PROPOSAL TO:

The Toro Company
8111 Lyndale Avenue South
Minneapolis, Minn. 55420

Attn: Mr. Mike Roy

# DEVELOPMENT OF ELECTRIC DRIVES

# FOR

# THE TORO GREENSMOWER 300

SUBMITTED BY:

Unique Mobility, Inc.
3700 South Jason St.
Englewood, Colorado 80110
(303) 761-2137

June 18, 1986



Exhibit A

TABLE OF CONTENTS

## 1.0 INTRODUCTION

Unique Mobility, Inc. ("Unique") is one of the oldest electric vehicle manufacturers currently engaged in the business of developing and producing electric vehicles and electric drive systems in the United States. Unique's effort in this field was launched in 1973 and has encompassed work for both the public and private sectors, including the U.S. Department of Energy (DOE) and the U.S. Department of Defense (DOD).

Unique's recent motor technology breakthrough has created the impetus for a number of electric transmission applications. Unique motors are extremely compact, lightweight with demonstrated power densities on the same order as acheivable with hydraulic drives. We believe "drive by wire" represents the future state of the art in vehicle propulsion systems and subsystems.

It is our understanding that Concept Engineering Company of Greeley, Colorado is currently working on concepts for an advanced greensmower for the Toro Company. Toro is the leading supplier of greensmowers to the golf course industry. The Greensmower 300 is a very popular and well-engineered machine. Hydraulic drives are currently being used for the mower reels as well as the wheels. Advanced concepts for further improving the existing machine include the use of electric motors to drive the reels as well as several other significant design changes.

Unique's motor/alternator technology is ideally suited for application to vehicles such as the existing Greensmower 300 as well as for any future designs under consideration.

The intent of our proposal is to demonstrate the possibilities and significant advantages of using electric wheel drive and electric reel drives over the currently employed hydraulic systems. To that end, we propose to take an existing Greensmower 300 and convert it to an all electric vehicle. To accomplish this, we will supply an engine alternator, 3 electric reel motors and 2 electric wheel motor/gear reduction units for primary propulsion of the vehicle. The existing engine will be used to drive the alternator.

We will apply our technology in such a way that the vehicle itself will behave and operate almost, if not identically, to the existing design.

The contract deliverable will include a working prototype conversion as described in Section 2.0 below together with a report of test results achieved, but will not include ownership or interest in Unique's proprietary technology embodied therein, if any.

Inasmuch as it may be necessary to exchange proprietary data with respect to the work proposed herein, it will be necessary for Toro and Unique to exchange confidentiality agreements prior to the commencement of work. A form of agreement generally used by Unique for this purpose is attached.

Should Toro wish to proceed with the program beyond evaluation of the prototype, Unique will undertake to supply, or to negotiate a license with a mutually acceptable third party manufacturer to supply Unique motors and alternators sufficient to meet Toro's requirements.

We at Unique are excited by the possibility of this project. We believe that it represents an excellent showcase for our technology. At the same time this project will allow Toro to advance the state of the art in its own field and by doing so maintain its competitive position as the leading supplier to the industry.

## 2.0 PROPOSAL

### 2.1 Technical Approach

With the cooperation of John Beattie, President of Concept Engineering, we were able to thoroughly inspect and study the Greensmower 300 unit at our own facility. After examining the design of the unit, we feel that it will be relatively straightforward to convert the Greensmower 300 to all electric drives by replacing the existing hydraulic reel and wheel motors with motors of our design and manufacture. In addition we will replace the existing hydraulic pump with one of our alternators.

We have given a considerable amount of thought as to how to best approach the project from a minimum cost point of view. Discussions with John Beattie have also been helpful in this regard.

We consider the project proposal to be one of demonstration of electric drive possibilities for Toro and its management. To that end we plan to use existing Unique designs and equipment as long as their use does not compromise any of the advantages inherent in electric drives for this application.

**Alternator**

We will use an existing Unique design for the alternator. This unit has a capacity of roughly 20 kw at 6000 RPM. It is a three phase device. RMS voltage is approximately 150 volts at 6000 RPM. Based on an engine speed governed at 3300 RPM, this will require a 1.8/1.0 drive pulley ratio. A double V-belt arrangement is envisioned. Power from the alternator will be rectified to roughly 120 volts DC using a commercially available 3 phase bridge curcuit employing power diodes.

**Reel Motors**

Three 1 HP - 1800 RPM reel motors will be configured and provided. We intend to use the same spline shaft arrangement that is employed with the current hydraulic drive.

Exhibit 1 shows the rough dimensions of the reel motor. The device will be of a brush-commutated design. A soft start circuit will be employed. It is expected that the motor will come up to the full speed of 1800 RPM in less than 2 seconds. ~~A time delay switch will be incorporated by Concept Engineering to avoid immediately shutting the reel motors off when the reels are lifted.~~ The reel motors will be designed for single speed operation - namely 1800 RPM at 120 VDC. Control will include the soft-start ~~and time delay mentioned above~~ as well as current (torque) limiting. This will prevent overloading the motor in the event that something causes the reel to jam.

## Wheel/Gear Motor

Vehicle speed requirements are understood to be as follows:

| | |
|---|---|
| 1st Gear (low) | 3.7 MPH |
| 2nd Gear (high) | 7.0 MPH |
| Reverse | 2.0 mph |

This corresponds to wheel rotation speeds of 130 RPM in high gear and 70 RPM in low speed range, based on an 18 inch wheel diameter.

Exhibit 2 shows a wheel/gear motor arrangement similar to the concept that will be employed in our proposed demonstration unit.

The wheel drive motors employed will actually be the same motor (but with a differnet winding arrangement) as that used for the reels. See Exhibit 1 projected performance data.

The wheel rim and tire used will be the same as currently employed. In addition, the existing drum brakes will also be used. In future designs, regenerative braking is a possibility worth considering. The wheel motors themselves will be designed to run at roughly 6000 RPM and put out a maximum of 3.5 HP each in the high speed range. Torque at the wheel will be 140 ft.-lbs. The characterisitics of our motor are such that this same or even slightly higher torque will be available in the low speed range.

## Speed Control

Speed control will be in response to foot pedal depression through both voltage and current limiting to the wheel motors. In low gear, full pedal depression will result in a maximum speed of 3.7 MPH on a level grade. In high gear, maximum speed will be 7 MPH. It is our expectation that the "feel" of the vehicle will be very similar to that currently experienced.

## Other Considerations

It is our understanding that Unique will be provided a functional Greensmower 300 unit but with the primary hydraulic system removed. The lift mechanism for the mowers is not being addressed at this time. The current plan is that Concept Engineering will incorporate a small (perhaps electric) hydraulic pump and valve system to allow the lift mechanism to function on the unit as received by Unique. It is our understanding and hope that the unit will be put in actual service in our area (at least initially) so that our engineers and designers will have the opportunity to fully evaluate the application. The result of a successful demonstration should lead to a final system design approach. The next step would be for us to design, build and test preproduction motors optimized both in cost and performance for the duty intended.

## 2.2 Project Plan and Schedule

The proposed scope of work requires approximately 1400 manhours of effort and will take approximately 16 weeks to accomplish. The detailed project plan and schedule is shown in Table 1.

The 5 key tasks are discussed briefly below:

Task 1 - Finalize System Requirements

Review all available information on the Greensmower 300. Firm-up design and operating requirements for each of the components: alternator (1), reel motors (3), wheel motors (2), gear reduction units (2), control system (1)

Task 2 - Detailed Component Design

Prepare the necessary design and production drawings to allow fabrication of each of the key components. For each motor, a computer design study will be made to help assure that the motors when produced will be able to successfully achieve their design objectives. Note that Unique employs the services of outside consultants to assist us in the power electronics area.

Task 3 - Component Fabrication

Fabricate each of the components. Address any special tooling requirements. Over 90% of the required fabrication work will be accomplished in our own facility. The minimal outside services that we may require are included as part of the materials expense.

Task 4 - System Assembly and Checkout

Assemble all of the components and purchased materials. Check out each item for both individual performance and system integration. This is the debugging stage. Some adjustements and possible component replacement, relocation, etc. is to be expected.

Task 5 - System Testing and Analysis

Test the system thoroughly at an actual golf course site. If possible, operate daily for a period of at least 2 weeks before delivery to Toro for approval and further evaluation. Analyze the results of the testing and provide a brief report to Toro summarizing our findings and making recommendations for future activity.

## 2.3 Pricing

Major project costs are manpower related. For cost purposes Unique uses separate hourly cost rates for four classes of staff: Expert/Specialist, Senior Technical, Technical, and Non-Technical.

The classification Expert/Specialist includes technical professionals and/or consultants considered as experts or specialists in their particular field. As such, these individuals typically have 25 or more years experience and have

TABLE 1

DETAILED PROJECT PLAN

DEVELOPMENT OF ELECTRIC DRIVES
FOR
THE TORO GREENSMASTER 300

| TASK | DESCRIPTION | MANHOURS EXPERT | SR TECH | TECH | NON-TECH | SCHEDULE WEEKS START | COMPLETE |
|---|---|---|---|---|---|---|---|
| 1 | FINALIZE SYSTEM REQUIREMENTS | | | | | 1 | 2 |
| 1.1 | OBSERVATIONS/INTERVIEWS | 4 | 4 | | | | |
| 1.2 | ALTERNATOR POWER REQUIREMENTS | 4 | 4 | | | | |
| 1.3 | REEL MOTORS | 4 | | | | | |
| 1.4 | WHEEL MOTORS/GEAR REDUCERS | 4 | 8 | 8 | | | |
| 1.5 | SAFETY AND OPERATING CONTROLS | 4 | 8 | 8 | | | |
| 2 | DETAILED COMPONENT DESIGN | | | | | 2 | 6 |
| 2.1 | ALTERNATOR | 4 | | 16 | | | |
| 2.2 | REEL MOTORS | 4 | | 16 | | | |
| 2.3 | WHEEL MOTORS/GEAR REDUCERS | 8 | | 24 | | | |
| 2.4 | COOLING REQUIREMENTS | 8 | 8 | 16 | | | |
| 2.5 | CONTROLS | 24 | 16 | | | | |
| 3 | COMPONENT FABRICATION | | | | | 6 | 10 |
| 3.1 | ALTERNATOR | | | | 120 | | |
| 3.2 | REEL MOTORS | | | | 300 | | |
| 3.3 | WHEEL MOTORS/GEAR REDUCERS | | | 8 | 240 | | |
| 3.4 | COOLING FAN | | | | 16 | | |
| 3.5 | CONTROLS | 24 | | | 80 | | |
| 4 | SYSTEM ASSEMBLY AND CHECKOUT | | | | | 10 | 12 |
| 4.1 | COMPONENT CHECKOUT | 4 | | 24 | 60 | | |
| 4.2 | SYSTEM ASSEMBLY | | | 16 | 80 | | |
| 4.3 | CHECKOUT/DEBUGGING | 24 | 8 | 16 | 40 | | |
| 5 | SYSTEM TESTING AND ANALYSIS | | | | | 12 | 16 |
| 5.1 | SHOP TESTS | 4 | 4 | 20 | 24 | | |
| 5.2 | FIELD TESTS | 4 | 4 | 20 | 40 | | |
| 5.3 | MODIFICATIONS/ADJUSTMENTS | 4 | | 8 | 24 | | |
| 5.4 | REPORT/RECOMMENDATIONS | 4 | 4 | 16 | | | |
| | | 136 | 68 | 216 | 1024 | | |

annual salary requirements greater than $50,000. Senior management personnel of Unique are also included in this category.

The category, Senior Technical Staff, includes senior engineering and management personnel, with a demonstrated record of professional attainment in their field, and typically with 15 or more years experience and a salary range in excess of $40,000.

The Technical Staff classification covers engineers of lesser experience and senior level designers with a salary range of $25-35,000. The Non-Technical classification includes shop personnel generally earning less than $25,000 annually.

Table 1, Detailed Project Plan, reflects our assumptions about the required scope of work and manpower distribution by labor classification discussed above.

Unique Mobility proposes to perform the work described above for the price of $39,700. Because of our extremely high interest in seeing this project move ahead, our pricing does not include a full markup nor any profit or fee. Our detailed estimate of manhours is included only so that Toro may properly evaluate the full nature of the work to be accomplished. The total amount of $39,500 represents a firm-fixed price for the scope of work presented herein.

## 2.4 Project Billing

Unique requires an initial payment of $10,000 prior to starting the work. Upon completion of the project and submittal of our report and recommendations along with delivery of the modified Greensmower 300, remaining payment is expected within 10 days.

# 3.0 UNIQ TECHNOLOGY

UNIQ technology has been derived from a highly efficient electromagnetic transducer that Unique's Vice President, Gene Fisher, first developed as a high speed computer tape drive motor for IBM Corporation some years ago. These transducers, scaled up and much altered from their IBM progenitors, can function as AC motor/alternators or DC motor/generators in either rotary or linear configurations.

Electromagnetic transducers are commonly used both to transform electrical power into mechanical power (i.e., motors) and to transform mechanical power into electrical power (i.e., alternators and generators). While several lightweight motor, alternator and generator devices have been designed to operate at high speeds, none appear to be capable of operation at high speed and high power. For example, state of the art high power density devices have been known to produce up to 0.6 horsepower per pound of weight intermittently, but none have demonstrated the capability to exceed that level continuously.

The essence of the proprietary UNIQ technology resides in the novel construction, combination and arrangement of transducer components so that continuous power densities in excess of 6 horsepower per pound of weight are obtainable.

Unique is presently developing a 6.5" diameter by 4.0" long advanced vehicle traction motor (the same device can also function as an alternator) which has a design weight of 10 lb. and is expected to provide 40 HP at 12,000 RPM. This motor is similar to a polyphase synchronous motor in terms of the winding and pole arrangement. Its torque is proportional to current and back emf is proportional to speed; we therefore describe it as selfsynchronous.

The configuration of the UNIQ motor (Exhibit 3) is of tube or sleeve design in which radially magnetized permanent magnets are mounted on two hollow cylindrical rotor elements which coaxially "sandwich" a radially thin hollow stator.

Multiple speed and torque characteristics can be achieved by mechanically connecting and reconnecting the stator windings in either parallel or series configurations, a significant advantage for traction motor applications.

The UNIQ motor is similar to a brushless dc motor in that commutation is by solid state electronics. Electronic commutation works by combining a logic controller and a power driver to switch power on and off to the motor windings to create a series of pulses whose timing and duration govern the motor's speed. The action of these power switches, and hence the motor's speed, can be tied through the logic unit to a manual control or to some externally sensed variable.

Results to date (March, 1986) indicate the prototype motor can reliably achieve a continuous output of 20 HP at 8,500 RPM, the upper speed limit of the present dynamometer test stand. Motor efficiency at this stage of development is 90% over virtually all of the speed range, with a peak efficiency in excess of 95%.

Inasmuch as the first stage prototype has demonstrated a power density roughly three times that of known state of the art machines (1.8 HP/lb vs. 0.6 HP/lb) it is felt the original design objective of 4.0 HP/lb can be met with concerted additional effort. Future test and motor optimization will concentrate on reducing the electrical resistance of the armature as well as on improving heat transfer to enable improved and higher speed operation for traction and other high torque applications.

## 4.0 KEY PERSONNEL

Unique recognizes that human resources are our most significant asset. Accordingly, a brief biographical sketch of our key technical and management personnel and consultants is presented below:

### 4.1 Unique Mobility Staff

<u>William M. Anderson</u>

BSME Marquette University

| | |
|---|---|
| MSME | Illinois Institute of Technology<br>National Science Foundation<br>Fellowship |
| Present Reponsibility: | Vice President Operations<br>Unique Mobility, Inc., Englewood, CO. |

Experience: 21 years. Joined Unique Mobility in February, 1986. Responsible for day to day operation of in house engineering, fabrication, assembly and testing functions.

Extensive technical and management background in design, research and development, and manufacturing of engineered products and systems.

Currently holds six patents. Has published several technical papers. Member ASME, SAE and ASHRAE professional societies. Also member Sigma Xi, Pi Tau Sigma and Tau Beta Pi honorary Societies.

Gene A. Fisher

| | |
|---|---|
| BS,ME in Physics | Requirements filled at Montana State College; University of Utah; Fresno State College; San Jose Jr. College |
| Present Responsibility: | Vice President Research and Development, Unique Mobility, Inc., Englewood, CO. |

Experience: 35 years. Joined Unique Mobiity in 1978. Directs high efficiency electric motor/alternator and energy storage research projects applicable to the design and manufacture of electric vehicles. Designed, built and tested large scale motoralternators, generators and Unique's proprietary rotary kinetic energy storage device (Accuverter).

Consulting Engineer for Control Data, Telex, Royal Typewriter, Pure Cycle, Udy Analyzer, Kryptonics and others.

Employed by IBM (16 years) at San Jose, California and Boulder, Colorado divisions. Conducted mechanical design of test equipment, tooling and product development engineering tasks on B70 bomber computer. Developed systems for automated tube testing, magnetic disk testing, high resolution microdot photography and copy machines. Developed precision tachometer for controlling motor position and velocity control. Designed and built IBM's high efficiency hollow cylinder computer tape drive now considered the industry standard.

Designed and built guidance motors for high speed (90 knots) torpedos; worked on actuator and control systems for Walleye Missile.

Patents: 50 patents in mass flow meter control systems, temperature sensing devices, magnetic's, optics, electromechanical devices and control system.

Ray A. Geddes

| | |
|---|---|
| BBA; MBA | University of Michigan Graduate School of Business; |
| JD | University of Michigan Law School |

Present Responsibility: Chairman and CEO, Unique Mobility, Inc., Englewood, CO.

Experience: 28 years. Joined Unique Mobility in 1981. Directs all advanced vehicle planning activities, including forward model programs, electric drive military vehicles and related special vehicle programs.

Product Development Consultant to Chrysler Corporation, Ford Motor Company, Moss Design and DeTomaso Industries (Maserati, Innocenti, Moto Guzzi and Bennelli).

Employed by Ford Motor Company (11 years). Responsible for sports car design, production and racing activities at special vehicle operation centers in Dearborn, Los Angeles, Slough (England) and Turin (Italy). Directed Ford's Italian Automotive Group (Ghia, Vignale and DeTomaso Modena). Implemented several special vehicle production programs including:

* AC Cobra (World Champion 1965)
* Shelby Mustang (SCAA Champion, 1965 1966)
* Ford GT Prototype (Three times Lemans winner)
* DeTomaso Pantera (Sports Car of the Year 1971)

John S. Gould

Present Reponsibility: President of Unique Mobility, Inc. Englewood, CO.

Experience: 25 years. Founded Unique Mobility (then Dune Buggy, Inc.) in 1967 and continues as Chief Operating Officer. Initiated, launched and coordinated all Unique's vehicle and component R & D programs beginning with the Bandit, Carriage, Alta and Fargo dune buggy kits and vehicles, the ElecTrek and ElecTruck electric vehicles, the EVEM motor and the Accuverter rotary kinetic device.

Established Unique's specialty composite fabrication facility and developed the sophisticated techniques required to produce a diverse assortment of composite products such as unique furniture, space age containers for radioactive materials and vehicle bodies.

Patents: Two in the field of automobiles.

Kevin R. Lewis

BSME — Metropolitan State College, Denver, Colorado

Present Reponsibility: Mechanical Design Engineer, Unique Mobility, Inc., Englewood, CO.

Experience: Joined Unique Mobility in 1985. Responsibilities include the design, testing and analysis of composite material components, along with the design of mechanical power transmission coponents. Previous experience includes oil and gas well testing and analysis.

National Dean's List 1983 84. Graduated Magna Cum Laude. Member Tau Alpha Pi National Honor Society and the American Society of Mechanical Engineers.

Roger A. Thornton

Present Responsibility: Chief Mechanic, Unique Mobility, Inc., Englewood, Colorado.

Experience: 20 years. Joined Unique Mobility in 1976. Responsible for prototype vehicle construction and metal fabricating activities. Trained in diesel and gasoline powered vehicle maintenance and repair with extensive experience in heavy trucks, hydraulic cranes, tracked vehicles and fork lifts.

Has engineered and built over 80 vehicles, many from the ground up, including oval track and drag racing cars, show cars, Unique's Electrek and Turbo Electrek electric vehicles and related special equipment. He replaced a clutch one Sunday night by adapting a tire casing (the only thing available) to the task, Has supervised crews of mechanics, but also works well alone.

Richard E. Watson

BA - Los Angeles Art Center School

Engineering Course Work: Ohio State University (1 year)

Present Responsibility: Director of Automotive and Industrial Design, Unique Mobility, Inc., Englewood, Colorado

Experience: 25 years (7 with Chrysler Corporation). Joined Unique Mobility in 1975. Responsible for product design, composite tooling design and cost analysis. Extensive background in vehicle concept design, body engineering, modeling, creative advertising, graphic and package design.

While with Chrysler, did the styling design for the 1959-1966 Dodge. Did extensive human factors engineering for instrument panels, etc.

David D. Wright

| | |
|---|---|
| Evan Pugh Scholar | Penn State University (Engineering Science) |
| Ph.D program in Thermodynamics | Dartmouth College |
| Present Responsibility: | Director of Advanced Research, Unique Mobility, Inc. Englewood, CO. |

Experience: 17 years. Various engineering positions with small R & D organizations in Hanover, NH and Boulder, CO. Designed the 40 HP UNIQ motor prototype. Specialist in interdisciplinary applications involving mathematics, physics, engineering, drafting testing and prototype development. Was chief engineer of record in the design of two robots, several gas and water turbines, electronic instrumentation for coal mines, infrared hygrometer, optical and ultrasound imaging peripherals, resistor metal film coating machines, paper feeder/automatic document handler for copying machines, one bladed windmill and quiet (90 db) rock drill.

Dean's list throughout college career; Honorary member Tau Beta Pi (Engineering), Phi Kappa Phi (Scholastic Achievement), Sigma Tau (Physics), Phi Mi Epsilon (Mathematics) and Phi Eta Sigma (Freshman Honors).

Publications in acoustics, electronics, fluid mechanics, stress analysis, optics, electromechanics and computer simulation. Two patents.

Leonard Worland

| | |
|---|---|
| Present Responsibility: | Manager - Machine Shop, Unique Mobility, Inc., Englewood, Colorado. |

Experience: 30 years. Held management positions in quality control and manufacturing engineering at Storage Technology Corp. Journeyman modelmaker with extensive background in high technology organizations, e.g. Ball Brothers Aerospace, General Dynamics (San Diego), Mullard Research Laboratories and Survey and General Instrument. Has prototyped a variety of scientific hardware including microwave equipment, fiber optics devices, surveying instruments and microscopes.

## 4.2 Consultants To Unique Mobility

Craig Cambier

| | |
|---|---|
| BSEE | Rochester Institute of Technology |

Present Responsibility: Consultant to Unique Mobility, Inc.
President, Cambier Circuits Concepts

Experience: 10 years. Comprehensive design capabilities in the power electronics area including power MOSFET applications and motor controllers. Also experienced with servo design, video display design, and microprocessor programming and interfacing. Background in computer programming includes assembly language coding, and Fortran, Basic and Pascal applications.

Previously employed at IBM, Storage Technology, Otrona Advanced Systems and Siemens Components Division. Currently holds 5 patents. Graduated Summa Cum Laude. Member of Tau Beta Pi honorary society.

S. Obha

MS Ind. Engineering — Illinois University of Technology
Ph.D Program — Waseda University, Japan

Present Responsibility: Consultant to Unique Mobility, Inc. and owner, Soleq Corporation,
Chicago, IL.

Experience: 33 years. Operates Soleq Corporation as a supplier of state of the art controllers, converters and chargers for Unique Mobility's battery powered ElecTrek road vehicle. This controller achieves 99.5% efficiency at full power and has logic for regenerative braking, charge limiting, discharge limiting, self surveillance, failure diagnosis, failure protection and graceful failure.

Also has state of the art proficiency in the design, prototyping and testing of other electromechanical devices such as accelerators, windmill chargers and regulators, cardreaders, cardpunchers, SCR's and CPU controller microwave components.

Carroll Shelby

Present Responsibility: Consultant to Chrysler Corporation and to Unique Mobility regarding special vehicle programs. Board of Directors of Unique Mobility, Inc.

Experience: 40 years. As a consultant to Chrysler Corporation (and formerly Ford Motor Co.) designed and developed several special performance vehicles including the Shelby AC Cobra, Mustang GT350/500, Ford GT Sport Racing Car, Sunbeam Tiger, Shelby Dodge Charger, Omni GLH and related components.

Founded and operates Carroll Shelby Enterprises (Distributor, Goodyear Racing Tires); Carroll Shelby Industries (Manufacturer, aluminum wheels) and Carroll Shelby Research, Ltd. (automotive R & D). Internationally acclaimed sports car racing driver from 1952 - 1960.

Victor Wouk

| | |
|---|---|
| BA Math & Physics | Columbia College (NYC) |
| MAEE | Cal Tech |
| Ph.D EE | Cal Tech (Magna Cum Laude) |

Present Responsibility: Consultant to Unique Mobility regarding electric and hybrid vehicle and nuclear harden ing of control systems.

Experience: 40 years. Member, International Electrotechnical Commission, 1970 to date; for NASA-Lewis, reviewed state of the art of hybrids throughout the world. Contributed to NASA report "State Of The Art Assessment of Electric and Hybrid Vehicles"; reviewed European propulsion systems for Electric and Hybrid Demonstration Project for Department of Energy. For Electric Vehicle Council, Edison Electric Institute, member of Executive Committe; Chairman, Technical Advisory Committee and representative to Battery Council International.

Technical Affiliations: American Association for the Advancement of Science - Fellow; Institute of Electrical and Electronic Engineers Senior Member, Past Chairman Subcommittee on Power Supplies, Past Chairman Reliability Group and Member Executive Committee, "Electric Vehicle Committee".

Patents: Approximately 10 patents granted in the field of electric vehicles, electronic speed and braking control, improved hybrid vehicles, high voltage power supplies and high power solid state electronics.

Publications: Over 35 publications in the field of electric and hybrid vehicles and electronic controls for electrics and hybrids. Eight publications in the field of solid state, high power, high efficiency power supplies (power conditioners).

## 5.0 FACILITIES AND EQUIPMENT

Unique currently leases facilities at 3700 South Jason Street, Englewood, Colorado. The facilities include engineering offices, an experiemental lab, prototype shop and composite fabrication shop. All machines, tools and test equipment required to construct working prototypes, low volume preproduction runs and production tooling operations are on the premises.

Unique also has a power laboratory for testing motors and controllers. This includes a dynamometer stand and power supplies capable of generating up to 200 volts DC at up to 400 amps using batteries. The lab contains standard electronic test equipment.

Unique also has access to the Soleq Corporation facilities in Chicago, Illinois. Located there are the resources required for design, component testing, prototyping and assembly of electronic control systems, power control units, converters, inverters and related solid state componentry.

Unique also has access to the Denver Research Institute at the University of Denver Applicable resources include a VAX 11/780 computer with UNIX, the Terminal Ballistics Laboratory, and underground blast test facility (located

in a leased Tital missile site) and the Cherry Creek Antenna Range.

## 6.0 RELATED WORK

Unique was organized in 1967 as a corporation (now publicly held) under the laws of the State of Colorado. Since its inception, the Company has moved from the fabrication of custom composite structures to the production of special offroad and over the road passenger vehicles having both conventional and electric drive. In recent years, research and development activities have been expanded to include ultra high efficiency motor/generators, electric propulsion systems, advanced composite structures and remote or autonomous robotic vehicle system design.

Unique's work on electric vehicle and advanced electric drive systems was launched in October, 1973. Since that time, Unique has invested over $5.5 million of private funds on electric vehicle development and related production facilities. The result of this effort is embodied in the ElecTrek, a state of the art vehicle that is not only aerodynamically styled, drivable and cost efficient, but also safe, reliable and production feasible. Based on operating data received to date, including extensive evaluation tests for the U.S. Department of Energy (DOE) conducted by the U.S. Army Mobility and Research Command, Reynolds Electrical and Engineering Co., Inc. and the Argonne National Laboratory, Unique believes the ElecTrek to be one of the most advanced examples of present day electric vehicle technology.

In addition to the ElecTrek production program, Unique has fabricated a number of special vehicles and vehicle components utilizing an integrated systems design approach. Chief among these were the mobile broadcast studio, UNIQ TURBO ELECTREK, used at the 1984 Olympic Games as well as several specialized composite body structures and electric drive systems for military land vehicles.

Unique was selected by ABC Television to design and construct the TURBO ELECTREK hybrid electric camera vehicle used for live coverage of the men's and women's Olympic marathon based upon referral from the DOE. The vehicle was delivered May 31, 1984 and was successfully used by ABC to cover the U.S. Olympic Men's Marathon Trials as well as the final Olympic events in Los Angeles.

In January, 1984, Unique was retained by General Dynamics Land Systems (GDLS) to supply consulting services with respect to a survey of available electric drive components and application analysis of these components in various concepts submitted to the U.S. Army Tank Automotive Command, Warren, MI. As subcontractor, Unique assisted GDLS in a comprehensive survey of existing electric drive componentry and will participate in the generation of new electric drive configurations for close combat vehicles, tanks and missile carriers.

Also in January, 1984, Unique was awarded Contract No. DAMD 1784C4050 by the U.S. Army Medical Research and Development Command under the Defense Small Business Innovative Research (SBIR) Program for Phase I development of an Electric Robotic Medical Support Vehicle. The mission assignment for this vehicle was to transit battlefield ambient terrain, arrive at casualities, determine if they are still living and allocate resources to retrieve them. A

prototype testbed has been fabricated to prove the concept and the planned electric drive system incorporates the Unique advanced drive technology.

In March, 1984, Unique was retained by GDLS to supply consulting services with respect to the design, procurement and installation of a telecommunication system for its Robotic Vehicle Development Testing and Demonstration Program. In June, 1984, Unique was commissioned by GDLS to design and build tooling and parts for the upper shell structure of the RRV1 mobile robot.

In February, 1984, Unique submitted a low cost Autonomous Land Vehicle (ALV) proposal to DARPA. The Unique composite structure and electric drive technology being developed for the Electric Robotic Medical Support Vehicle was offered as an innovative solution to DARPA¶s need for an affordable common vehicle and testbed configuration. Unique has since been subcontracted by DARPA¶s integrating contractor, Martin Marietta Denver Aerospace, to design, engineer and fabricate a composite ALV body for this high visibility demonstration program. The assignment was completed on time and on budget. Delivery was effected on March 4, 1985 and the first press demonstration of the project ocurred in May, 1985.

In June, 1985, Unique was retained by GDLS to develop and build a 360 degree steerable wheel module for the RRV2 mobile robot. The module will utilize a 20 HP UNIQ motor design fitted inside the wheel. The development of algorithms for steering and brake servo systems is also included in this assignment.

In September, 1985, Unique was awarded Contract No. N6092185C0267 by the Naval Surface Weapons Center White Oak under the "SBIR" Program for Phase I development of a Resonant Stirling Engine Generator.

In April, 1986, Unique received a contract award DEV-6005037 to develop concepts for the Tele-Operated Mobile Anti-Armor Platform (TMAP).

Unique, through its UK subsidiary, Unique Technology, Ltd. has received a contract from a major British automaker to conduct an electric drive/transmission feasibility study and to provide a 40 horsepower motor for brush testing and evaluation. The complete program, if successfull and pursued could lead to introduction in the early to mid 1990s of a high performance (160 MPH) luxury car with independent 4 wheel drive using electric transmission. Several US automakers have recently expressed interest in this technology as well.

## 7.0 SMALL BUSINESS CERTIFICATION

Unique Mobility, Inc. represents and certifies as part of this proposal that it is a corporation organized under the laws of the State of Colorado and that it is a small business concern under criteria established by the Small Business Administration as prescribed by the Code of Federal Regulations, Title 13, Part 12, as amended.

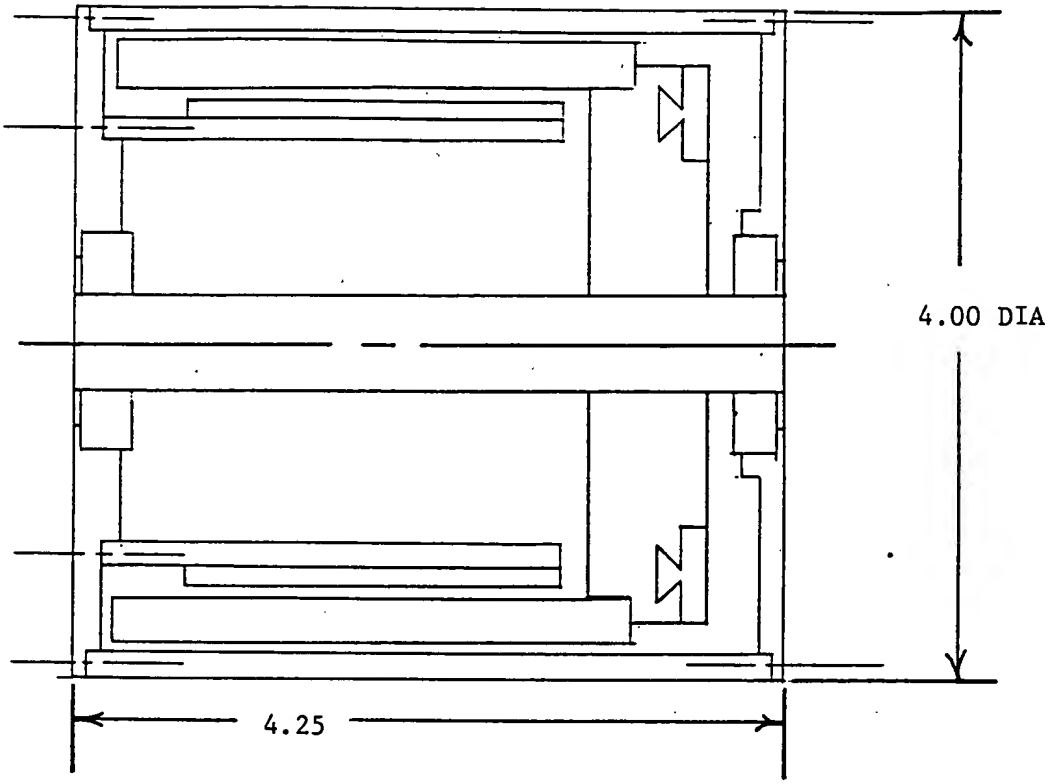
## 8.0 CORPORATE REPRESENTATIVES

The following officers of the Corporation are authorized to represent the offeror in contractual matters:

| R. A. GEDDES | J. S. GOULD |
|---|---|
| Chief Executive Officer | President |

Both of the above can be reached at the following address:

Unique Mobility, Inc.
3700 South Jason
Englewood, Colorado 80110
(303) 761-2137



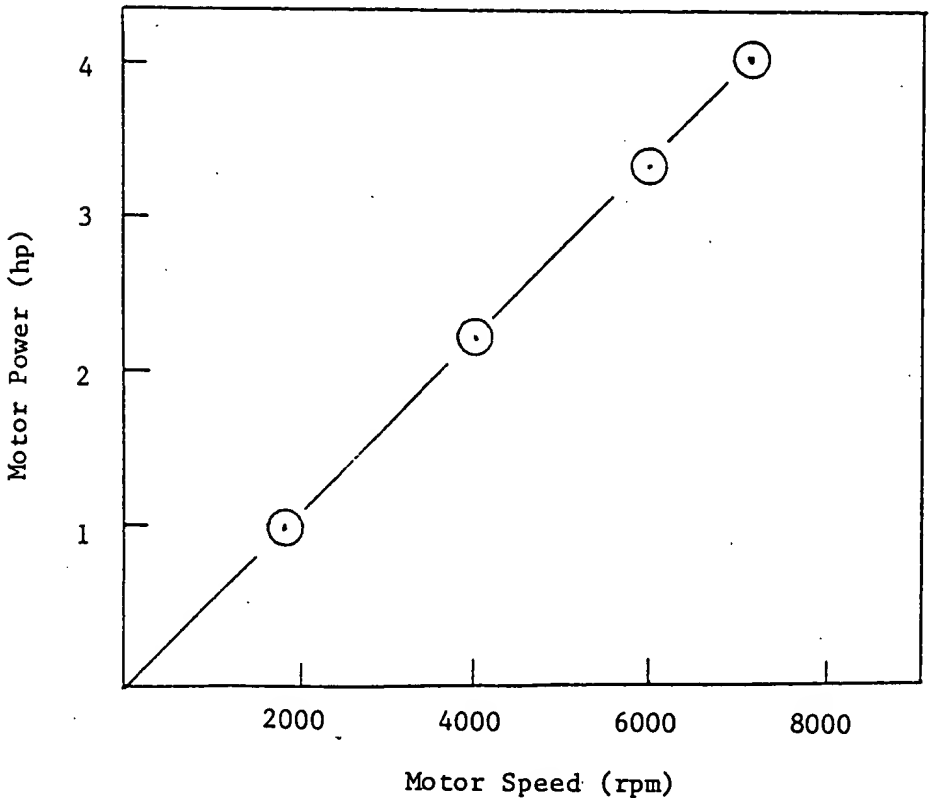




Exhibit 1. 1hp to 4hp Brush Commutated Motor

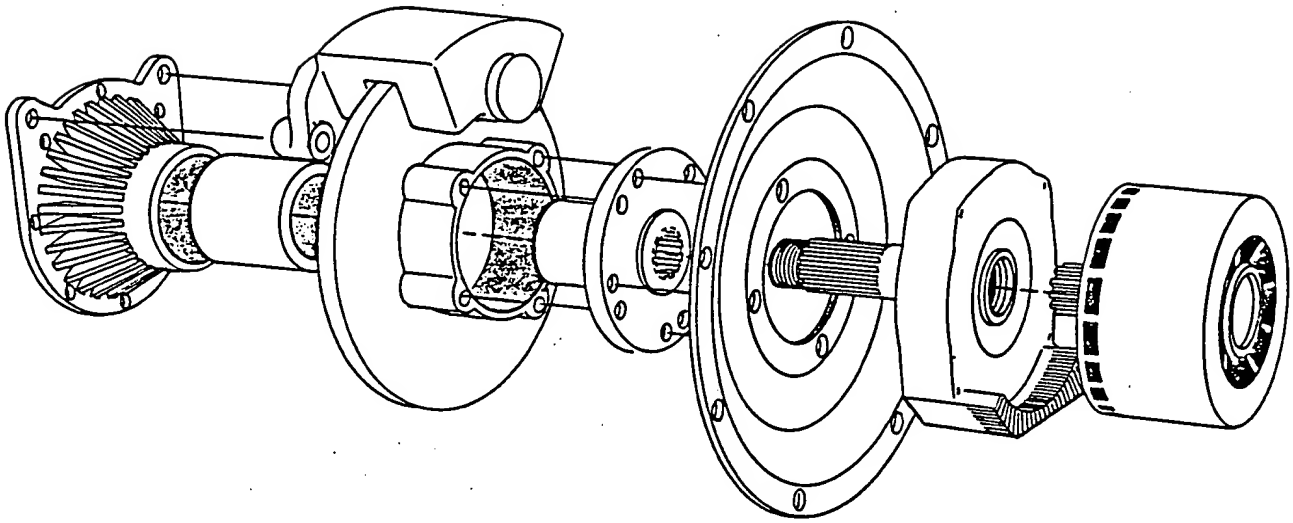
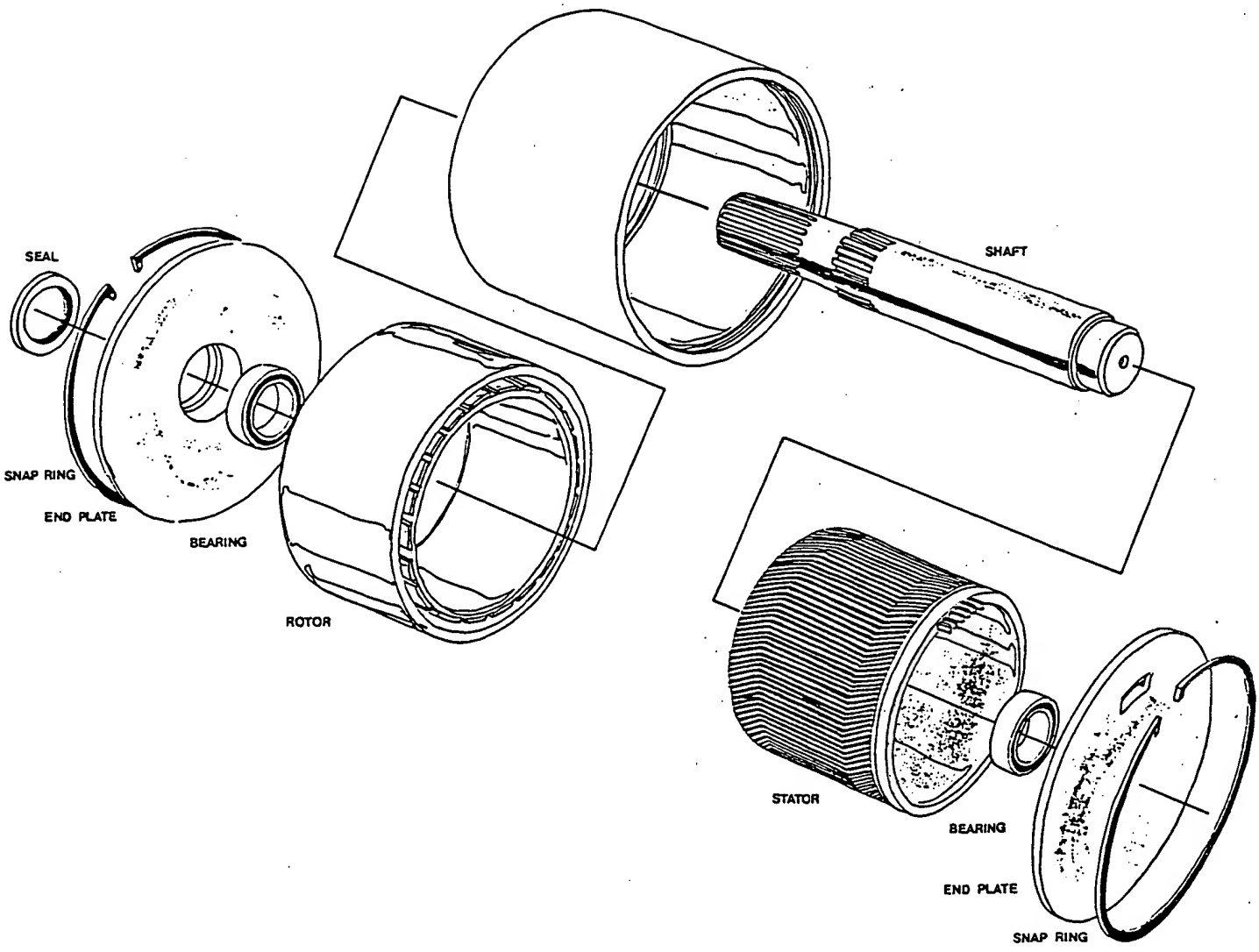


Exhibit 2. Wheel Motor Concept




Exploded View of UNIQUE Motor/Alternator.

Exhibit 3